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ABSTRACT

The MCNP[1] code was used to generate time and energy spectra for neutron and photon transport throughout a fictitious facility. Calculations of this type will be utilized to design a new Los Alamos criticality alarm system.

INTRODUCTION

Plans are underway at Los Alamos for the construction of a new Special Nuclear Materials handling facility. The plans include a criticality alarm system. The purpose of this presentation is to outline our approach in the design of this new system.

DESIGN SCHEMATIC

Figure 1 outlines the steps in our planning process. The first box refers to the question of what types of systems could, in principle, lead to a criticality accident. The adjective "postulated" is used here because it seems unlikely that actual criticality excursions will be "created" to check out the operation of the alarm system. The technical substance of this stage is to specify the output of the postulated accident; that is, the energy and time dependance of neutrons and photons leaving the accident system. These quantities have to be specified on an absolute scale.

The second box addresses the transport of neutrons and photons away from the accident site throughout the facility. To carry out this part of the design process requires specifying not only the location of the criticality accident but also the facility geometry. Materials of construction also need to be specified. Determination of detector locations is an integral part of this process.

The third box, labelled "detector response", covers a host of detector issues. The issue of detecting neutrons or photons (or both) is part of this box. In addition, selection of the transducing medium and all aspects of detector geometry and electronics are part of this box. A possible consideration at this stage of design is the question of whether or not to directly convert the detector output to a dose value

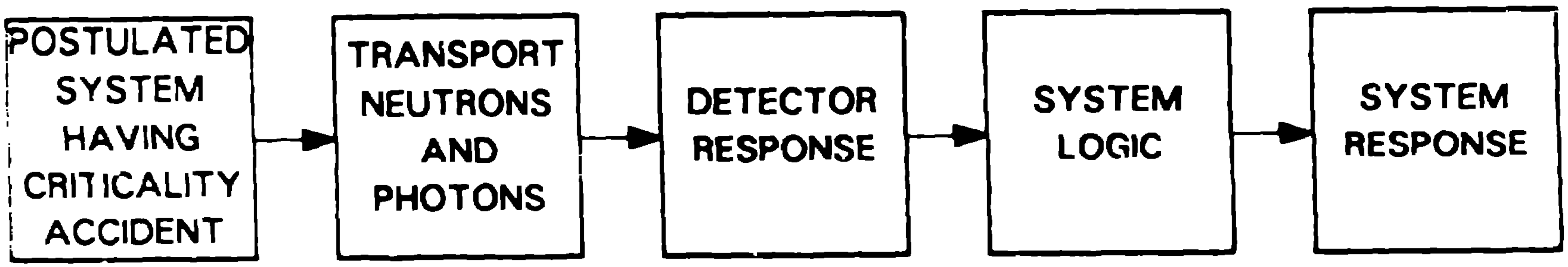

FIGURE 1. Schematic of steps used in designing the criticality alarm system.

The fourth box, labelled "system logic", is a classic part of alarm system design. The question here is how to specify a logic system which will have high probability of alarming for a criticality accident, and, at the same time, a low probability that false alarms will occur. The dynamic range and time response of the detectors will play an important role in this question. If the system is to be used as an on-line, real time dose monitoring system, then this logic box could be more complex than required for a simple alarm/no alarm system.

Finally, the last box lumps together the remaining issues of the design; that is, horns, evacuation procedures, documentation, etc. One feature that might be considered here is the archiving of episodes where detectors record levels of radiation which are significantly-above-background but below alarm thresholds. Such information might be useful to facility managers.

TRANSPORT CALCULATIONS

We have elected to explore Box Two--the transport of neutrons and photons within the facility. Our reasons for this are twofold. First, we believe that this portion of the design problem has traditionally not been performed very well. Second, we have at Los Alamos a computational tool (the MCNP code) capable of addressing this problem. Since our new facility has not yet progressed beyond preliminary sketches, we chose to create a fictitious facility. The geometry is shown in Figure 2. The two intersecting hallways are each four meters wide and five meters high. Each room is ten meters wide by twenty meters long by five meters high. The geometric thickness of the walls is 25 centimeters, as are the roof and floor. The roof is shown as transparent in order to display the internal geometry of the facility. The darker shaded walls are considered interior walls, whereas the lighter shaded walls, along with the roof and floor, are considered as exterior. The distinction between interior and exterior is that interior walls are modelled as five centimeters equivalent thickness of water, whereas exterior elements are modelled as ten centimeters equivalent thickness of water. Water was chosen as the building material. This was done to avoid the complexities of real building materials and provides a reference material that is somewhat similar to concrete. For the results presented below, the criticality accident was assumed to occur at the intersection of the hallways, one meter above floor level. The nineteen spheres represent potential detector locations. The center of each sphere is located one meter below the ceiling, and has a volume of one cubic meter. The spheres were modelled as having void interiors. Figure 3 shows a close up view of the postulated criticality accident location. As a particle trajectory passes through the volume of a detector sphere, the trajectory path length within the sphere is tallied.

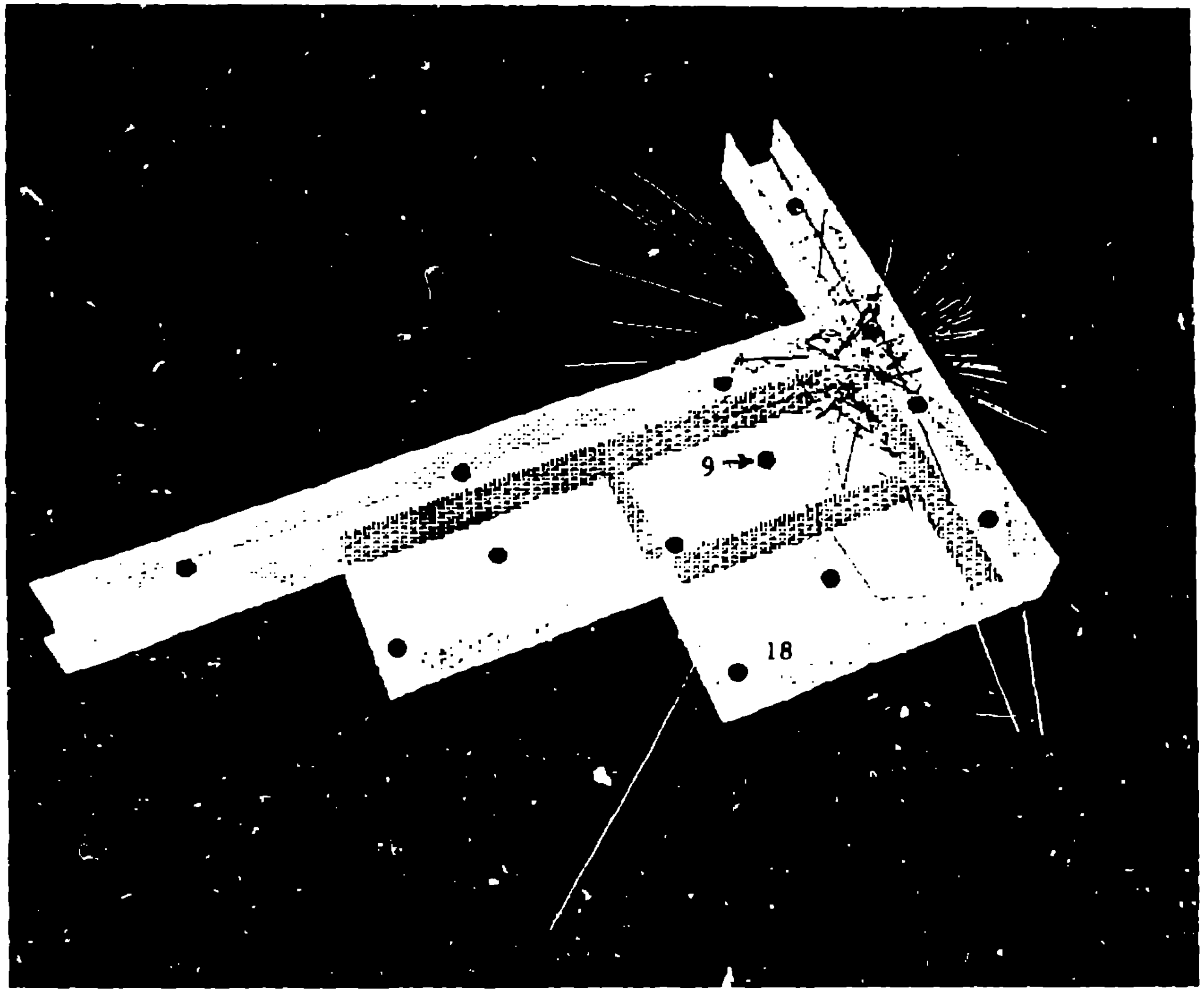

FIGURE 2. Model of fictitious building used to demonstrate neutron and photon calculations. Spheres represent detector locations. Calculated particle trajectories are illustrated.

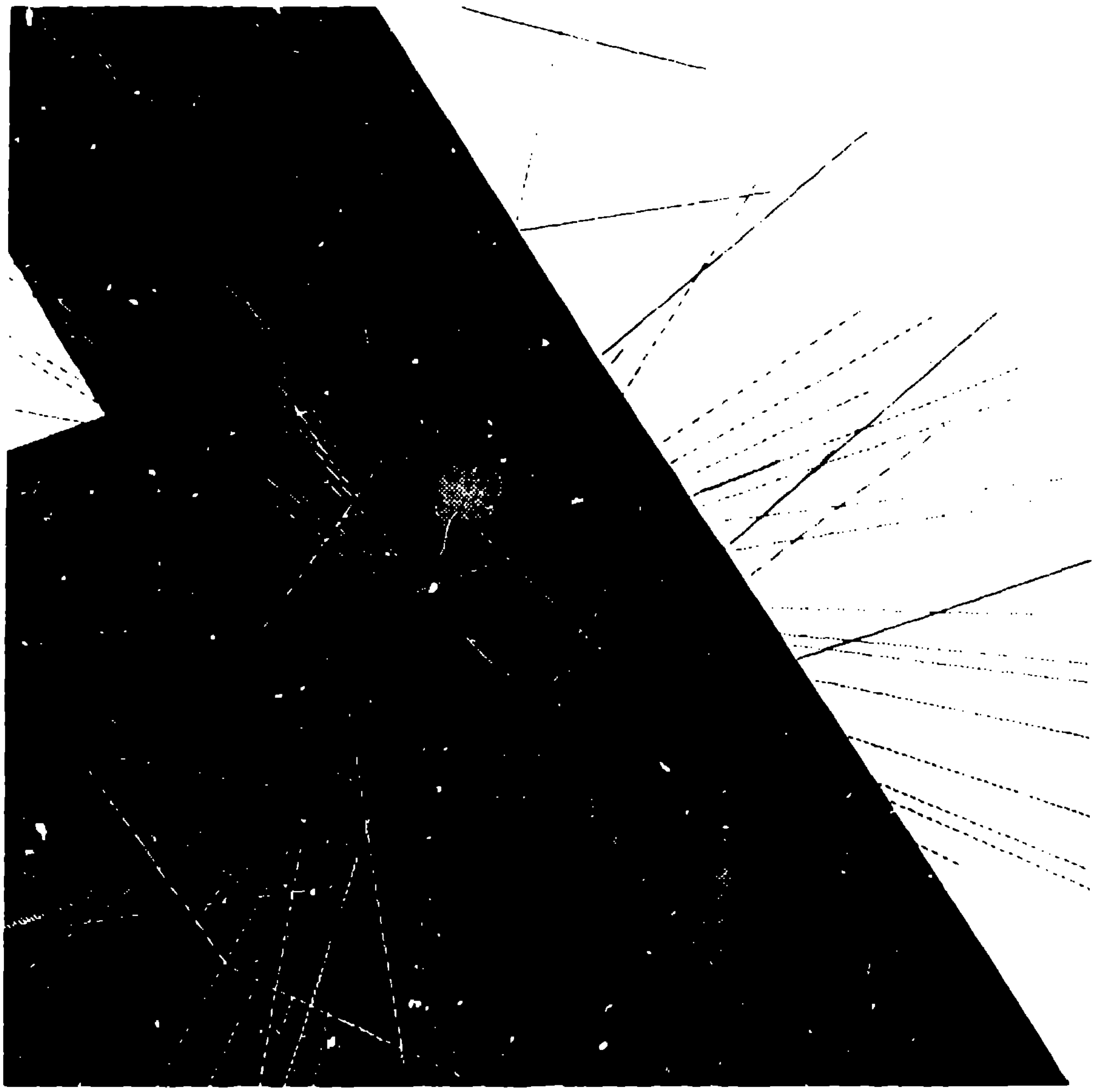

FIGURE 3. Close-up view showing sphere used to model location of criticality accident at hallway intersection. Original figure is in color, with color coded trajectories to display particle energy. Two adjacent detector spheres are also shown.

In order to examine the time and energy spectra at a detector location, time and energy bin boundaries were specified to define a gridwork of rectangles on a plane containing a Cartesian time-energy coordinate system. For each rectangle, MCNP sums the trajectory lengths within the rectangle and divides by the sphere volume and the number of particles started at the source point. This produces an estimate of the time-integrated flux at the sphere--a quantity having units of inverse centimeter squared. That is the time-integrated flux, where time is integrated over the time interval of the bin for trajectories corresponding to particle energies within the energy bin. All particles were assumed to leave the source at time equal to zero.

In order to examine the effects of the output energy spectra of a criticality accident, three energies were selected as the starting source energies for neutrons and photons. These energies were 0.5, 1.0, and 5.0 Mev. Therefore, six calculations were performed: three for neutrons and three for photons. The source was modelled as a point source with isotropic angular distribution. Neutron histories were terminated when the neutrons migrated beyond the specified problem boundaries. These boundaries are defined by a cuboid whose planes correspond to the bottom of the floor, top of the roof, far end of the shorter hallway (on the right hand side in Figure 2), left end of the longer hallway, an invisible plane 11.75 meters to the right and parallel to the outer wall of the shorter hallway, and an invisible plane 14.25 meters beyond the near end of the shorter hallway. Neutron histories were also terminated by rouletting if neutron weight fell below one-fourth of initial neutron weight. Photon histories were terminated by the same problem boundaries or, again, by rouletting on particle weight . No other variance reduction techniques were used.

The six calculations were carried out on a Cray computer To create particle tracks, each of the six calculations was run with two hundred particle histories. A sample of one of these calculations is presented in Figures 2 and 3 . These figures are black and white reproductions of color graphics produced by the SABRINA[2] code. To create energy and time spectra, each of the calculations was run with 100,000 and 500,000 particle histories for neutrons and photons respectively. Running times on a Cray computer were 74 minutes or less for neutrons and 13 minutes or less for photons. Flux errors corresponding to one standard deviation for these calculations were in the range of 17% or less for neutrons and 7% or less for photons. The time-energy rectangles described above were then used to estimate time-energy spectra by plotting the time-integrated flux as a function of time and energy. For neutrons, the time and energy axes are logarithmic, whereas for photons they are linear. The vertical scale, displaying time-integrated flux, is linear for both neutrons and photons. Samples of the results are presented in Figures 4 through 7. For these figures the particle source energy was 1 Mev. Persons interested in examining the voluminous results corresponding to other detector locations and source energies should contact one of the authors.

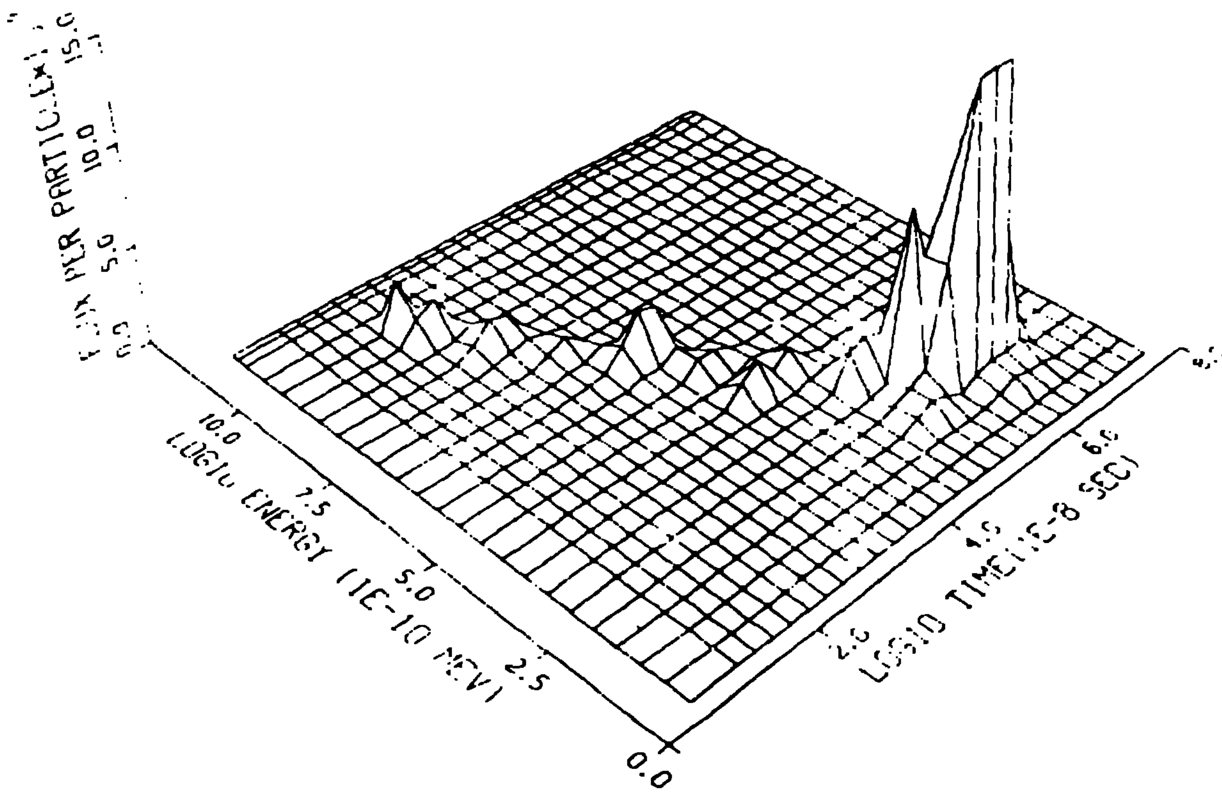

FIGURE 4. Calculated neutron energy and time spectra for detector 9. Detector location is shown on Figure 2. Source energy is 1.0 Mev.

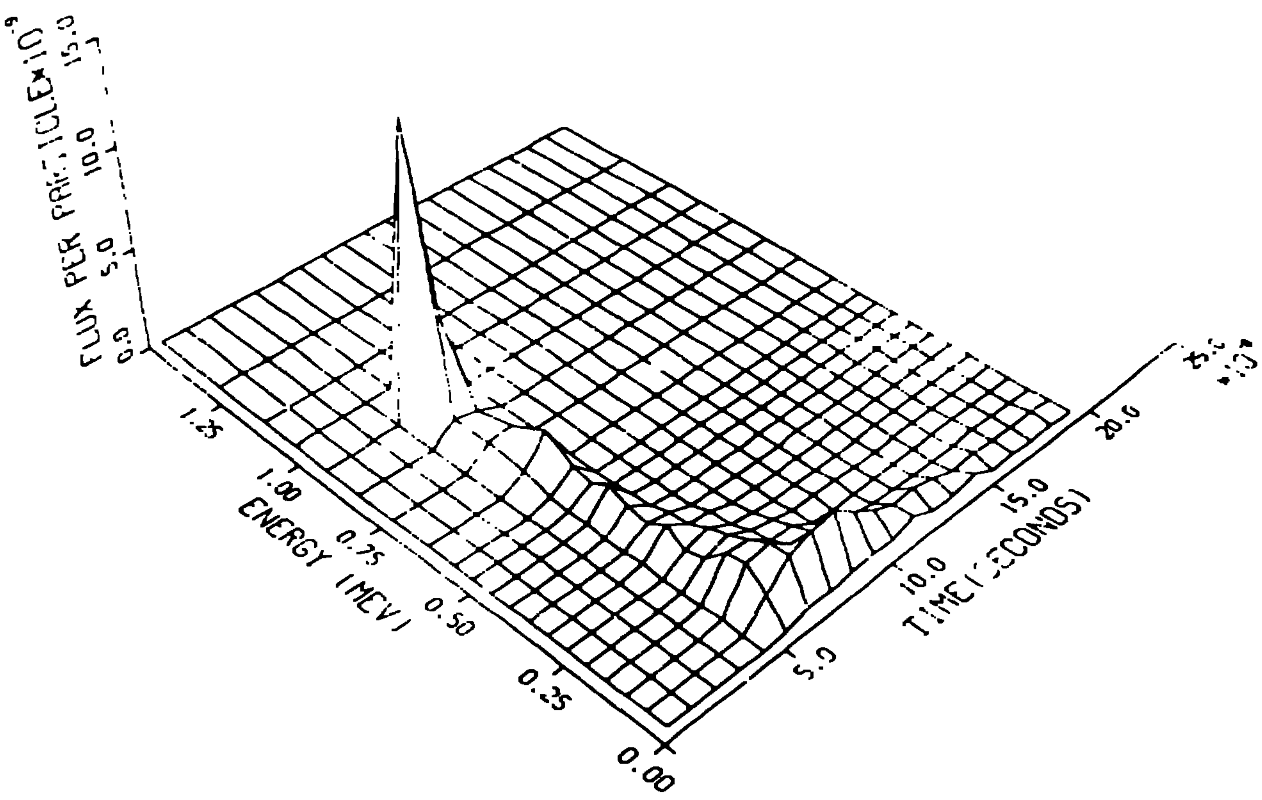

FIGURE 5. Calculated photon energy and time spectra for detector 9. Detector location is shown on Figure 2. Source energy is 1.0 Mev.

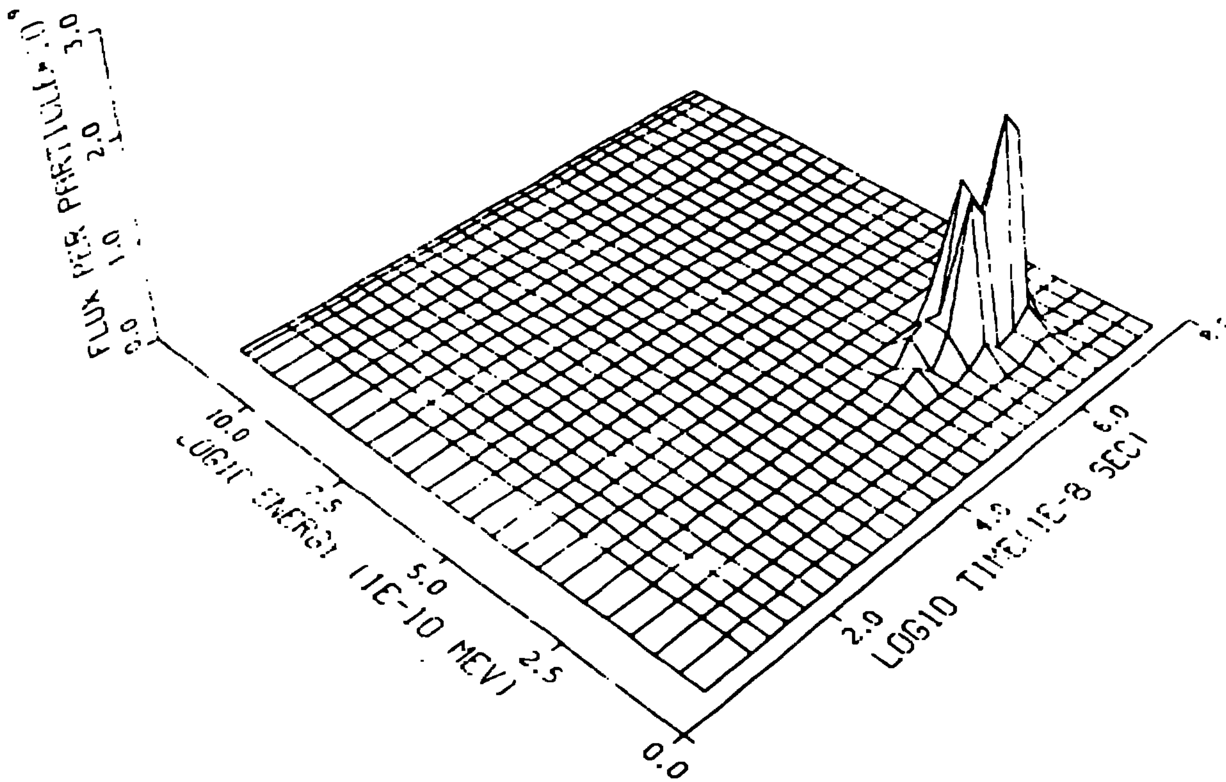

FIGURE 6. Calculated neutron energy and time spectra for detector 18. Detector location is shown on Figure 2. Source energy is 1.0 Mev.

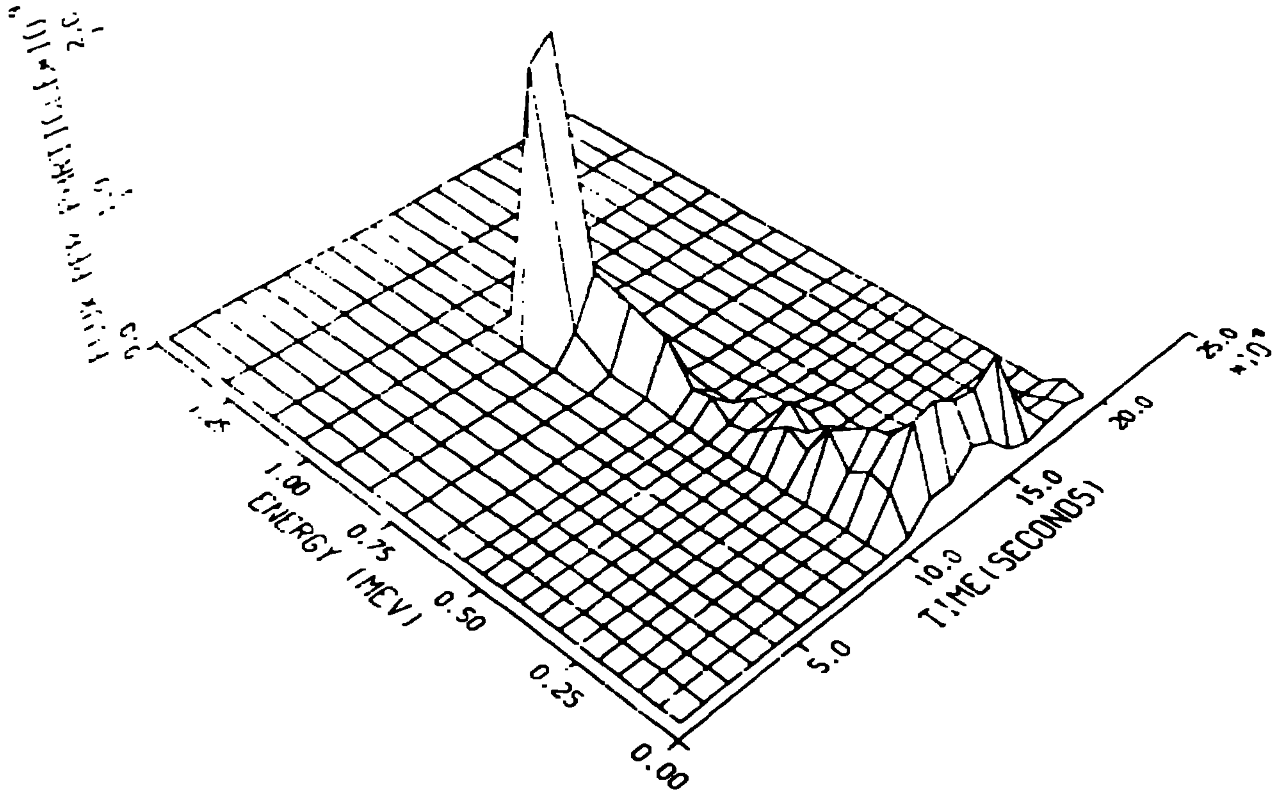

FIGURE 7. Calculated photon energy and time spectra for detector 18. Detector location is shown on Figure 2. Source energy is 1.0 Mev.

CONCLUSION

Design of the new alarm system at Los Alamos will utilize MCNP for determining detector locations. When designed, the facility geometry and materials will be modelled in detail to estimate the relationship between accident spectra and detector time-energy spectra, rather than to rely on the simpler strategies used in the past.

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